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(84) Alkali- and heat-resistant inorganic fiber.

(85) The inorganic fiber of this invention comprising as major constituents

	% by weight
SiO <sub>2</sub>	40-50
CaO	0-10
MgO	15-25
Fe <sub>2</sub> O <sub>3</sub> + FeO	0-10
Al <sub>2</sub> O <sub>3</sub>	5-15
MnO	2-15

(provided that the total amount of CaO, Fe<sub>2</sub>O<sub>3</sub>, FeO and MnO is limited within 20% by weight) is excellent in alkali- and heat-resistances and is useful as a replacement of asbestos in asbestos-cement boards.

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## ALKALI- AND HEAT-RESISTANT INORGANIC FIBER

## 1 BACKGROUND OF THE INVENTION

## FIELD OF THE INVENTION

This invention relates to an alkali- and heat-resistant inorganic fiber and, more particularly, to  
5 alkali- and heat-resistant inorganic fibers, in which the fiberizing temperature is approximately the same as those of customary rock fibers.

## DESCRIPTION OF THE PRIOR ART

Heretofore, some of glass fibers have been  
10 known as alkali-resistant inorganic fibers. These glass fibers, however, show a high viscosity in the molten state such as, for example, 100 poises at 1,400°C.  
Owing to such high viscosity, it is unable to manufacture short fibers by a multirotor spinning process, which  
15 operates only under low melt viscosity conditions as in the case of rock fibers with a viscosity of several poises at 1,400°C. Moreover, there are other disadvantages for producing the alkali-resistant glass fibers. It is necessary to add zirconium oxide, which is expensive  
20 and, furthermore gives rise to an increased melting cost.

There has recently been disclosed alkali-resistant rock fibers which dispense with expensive zirconium oxide used in conventional alkali-resistant glass fibers [Japanese Patent Application "Kokai"

- 1 (Laid-open), No. 101,922/1979]. The disclosed fibers, however, have considerably high fiberizing temperature, comparing with those of customary rock fibers. This causes a remarkable increase in energy cost for manu-  
 5 facturing fibers of optimal diameter by means of a multirotors.

## SUMMARY OF THE INVENTION

An object of this invention is to provide the alkali- and heat-resistant inorganic fiber manufactured  
 10 by utilizing those natural rocks, slags and the like which are sufficiently available from the viewpoint of resources.

Another object of this invention is to provide the alkali- and heat-resistant inorganic fiber which  
 15 can be manufactured economically by multirotor spinning process.

According to this invention, there is provided the alkali- and heat-resistant inorganic fibers comprising as major constituents

	% by weight
$\text{SiO}_2$	40 - 50
$\text{CaO}$	0 - 10
$\text{MgO}$	15 - 25
$\text{Fe}_2\text{O}_3 + \text{FeO}$	0 - 10
$\text{Al}_2\text{O}_3$	5 - 15
$\text{MnO}$	2 - 15

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- 1 (provided that the total amount of  $\text{CaO}$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{FeO}$   
and  $\text{MnO}$  is limited within 20% by weight).

#### BRIEF DESCRIPTION OF THE DRAWING

- Fig. 1 shows an electron microscopic photo-  
5 graph of the rock fiber specimen of Comparative Example  
1 in Table 1, which has been subjected to the alkali  
resistance test.

- Fig. 2 shows an electron microscopic photo-  
graph of the alkali- and heat-resistant rock fiber  
20 specimen of this invention (Example) in Table 1, which  
has been subjected to the alkali resistance test.

#### DETAILED DESCRIPTION OF THE INVENTION

- When one intends to obtain simply good fibers  
from a batch material having comparatively low viscosity  
15 without paying attention to the alkali and heat-resist-  
ance, the  $\text{SiO}_2$  content of the meltable material should  
be in the range of 35 to 50% by weight. If the  $\text{SiO}_2$   
content is below 35% by weight, it is difficult to  
obtain good short fibers of 2 to 10  $\mu\text{m}$  in diameter,  
20 whereas if the  $\text{SiO}_2$  content exceeds 50% by weight, the  
fiber formation by the multirotor spinning process  
becomes difficult owing to an increased melt viscosity.  
However, in view of the alkali and heat resistances  
intended in this invention, it is desirable to increase  
25 the  $\text{SiO}_2$  content, and if the  $\text{SiO}_2$  content is less than  
40% by weight, it is difficult to obtain the fibers

- 1 having satisfactory alkali and heat resistances, relating  
to the content of other alkaline oxides. After all,  
it is necessary that the  $\text{SiO}_2$  content should be in the  
range of 40 to 50% by weight, most preferably 45 to  
5 50% by weight.

For the purpose of improving the strength and  
heat resistance of fibers, the  $\text{CaO}$  content of the  
melttable material should be confined within 10% by  
weight. If the  $\text{CaO}$  content exceeds 10% by weight, the  
10 heat resistance, as well as physical properties of  
fibers, will be lowered. The most preferable  $\text{CaO}$  content  
is in the range of 0 to 6% by weight.

In the sense of replenishing the above defect  
of  $\text{CaO}$  and to adjust the viscosity of the melttable  
15 material to a value suitable for the multirotor spinning  
process,  $\text{MgO}$  should be present in an amount of 15 to  
25% by weight. If the  $\text{MgO}$  content exceeds 25% by weight,  
not only the melt viscosity becomes too low to keep  
the optimal fiber formation, but also to secure the  
20 necessary amount of acidic oxides, resulting in lowering  
the alkali resistance of the fiber. On the other hand,  
if the  $\text{MgO}$  content is less than 15% by weight, the  
melt viscosity becomes too high to be suitable for the  
fiber formation. The most preferred  $\text{MgO}$  content should  
25 be in the range of 18 to 23% by weight.

$\text{Fe}_2\text{O}_3$  and  $\text{FeO}$  are useful in improving the  
heat resistance and flexibility of the fiber of 2 to  
10  $\mu\text{m}$  in diameter. However, if their content exceeds 10%

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1 by weight, the alkali resistance of the fibers will be lowered. The most preferable content of  $\text{Fe}_2\text{O}_3$  plus  $\text{FeO}$  should be in the range of 0 to 8% by weight.

Alumina ( $\text{Al}_2\text{O}_3$ ) as well as silica ( $\text{SiO}_2$ )

5 is effective in improving the fiber strength. However, with the increase in the  $\text{Al}_2\text{O}_3$  content, the melt viscosity becomes higher and the devitrification temperature increases, resulting in an increase in melting energy cost. If the  $\text{Al}_2\text{O}_3$  content exceeds 15% by weight, the  
10 alkali resistance of the fibers will be lowered, whereas if it is below 5% by weight, good fibers may not be obtained. Therefore, the  $\text{Al}_2\text{O}_3$  content should be restricted to the range of 5 to 15% by weight; the most preferable content is in the range of 5 to 10% by weight.

15 Manganese oxide ( $\text{MnO}$ ) has favorable effects of producing a uniform melt, and also of imparting the good alkali resistance to the fibers. In the case of the rock fibers, unlike the glass fibers, the addition of 2 to 15% by weight of  $\text{MnO}$  produces a sufficient  
20 decrease in melt viscosity and exhibits stabilizing and clarifying effects for the melt. For instance, the addition of 5% by weight of  $\text{MnO}$  will decrease the optimal fiber forming temperature by about  $80^\circ\text{C}$ . However, the addition of  $\text{MnO}$  over 15% by weight is not only un-  
25 necessary but also undesirable to secure the necessary amount of  $\text{SiO}_2$  for the optimal fiber formation. If the  $\text{MnO}$  content is below 2% by weight, the function of  $\text{MnO}$  as a flux is no longer exhibited. The most preferable

- 1 MnO content is in the range of 5 to 10% by weight.

Apart from the above-mentioned specification for each constituent, the total amount of MnO, CaO,  $\text{Fe}_2\text{O}_3$  and FeO should be within 20% by weight, because  
5 the total of 20% by weight makes the viscosity of the meltable material to the optimal level for the fiber formation by the multirotor spinning process. The superfluous addition of these constituents causes a negative factor for keeping the necessary amount of  
10  $\text{SiO}_2$  effective for the alkali resistance.

Titanium oxide ( $\text{TiO}_2$ ) is contained in natural rocks or slags to be used for the meltable material as an impurity in the amount of about 2% by weight.

The major natural rock material to be used  
15 as raw material in producing the inorganic fibers of the composition as herein specified is found in olivine and metamorphous rocks thereof containing each 35% by weight or more of  $\text{SiO}_2$  and MgO. Olivine has an advantage of being naturally occurred anywhere throughout Japan  
20 and available as raw material at low price.

A typical metamorphous rock of olivine is serpentine which can be used as a complete or partial substitute for olivine. However, as compared with olivine, generally the MgO content is smaller by about  
25 5% and the  $\text{Fe}_2\text{O}_3$  content is larger by about 3%. It is, therefore, advantageous to use olivine from the economical and other viewpoints. In order to obtain the starting material of the composition as herein specified, one needs

- 1 to adjust the composition of the above-noted major natural rock material by adding the calculated amounts of basalt, diabase, vermiculite, pyrophyllite, and iron ore slag for  $\text{SiO}_2$ ,  $\text{CaO}$  and  $\text{Al}_2\text{O}_3$ ; silica stone
- 5 and silica brick for  $\text{SiO}_2$ ; and manganese silicate ore, manganese carbonate ore, manganese oxide ore, and silico-manganese slag for  $\text{MgO}$ . The selection and combination of these natural ores or slags are not subject to any particular restriction, unless the final composition
- 10 departs from that specified herein.

In manufacturing the alkali- and heat-resistant inorganic fibers of this invention by using the said natural rocks and slags, conventionally well-known equipments and methods can be applied. For instance,

15 the compounded raw material is melted in a cupola by heating at  $1410^\circ$  to  $1460^\circ\text{C}$ , the resulting melt is allowed to flow downward onto the surface of spinning rotors to fiberize the molten material, and the fibers formed in this way is collected by means of an air stream blown-

20 off around the spinning rotors.

#### Example

The compounded raw material according to this invention, shown in the column of Example in Table 1, was melted in a conventional cupola by heating at  $1,430^\circ\text{C}$ .

25 The resulting melt was allowed to flow downward onto the surface of spinning rotors to fiberize the molten material, and the fibers formed in this way were collected



1 by means of an air stream blown-off around the spinning rotor.

In Comparative Examples 1 and 2, the compounded raw materials shown in Table 1 were also formed into  
 5 fiber and collected in the same manner as described above, except that the raw materials were melted at 1,460° and 1,540°C, respectively, which were the optimal fiber forming temperatures as shown in Table 2.

Table 1

Comparative Example 1	Comparative Example 2	Example
Slag 91%	Basalt 55%	Basalt 45%
Silica stone 9	Olivine 40	Olivine 40
	Silica stone 5	Silica stone 10
		Manganese oxide ore 5

The composition and characteristics of the  
 10 inorganic fibers obtained according to this invention were shown in Table 2, where are also shown the compositions and characteristics of other rock fibers not covered by the present invention (Comparative Examples 1 to 3).

Table 2

	Comparative Example 1	Comparative Example 2	Comparative Example 3	Example
SiO <sub>2</sub>	39.4%	45.0%	47.3%	45.8%
CaO	37.4	16.0	5.4	5.6
MgO	5.3	14.9	23.6	22.3
Fe <sub>2</sub> O <sub>3</sub> + FeO	0.5	5.4	8.4	8.1
Al <sub>2</sub> O <sub>3</sub>	13.4	16.7	12.5	9.6
MnO	-	-	-	4.1
TiO <sub>2</sub>	1.7	0.5	1.1	1.5
Others	2.3	1.5	2.6	3.0
Melt viscosity				
1500°C	4.8 poises	9.0 poises	5.3 poises	3.2 poises
1450°C	6.5	11.0	6.9	4.5
1400°C	8.8	15.3	11.0	6.4
1350°C	14.0	23.0	30.0	11.0
Optimal fiber-forming temperature	1430 - 1480°C	1510 - 1560°C	1480 - 1530°C	1410 - 1460°C

- Cont'd -

Table 2 (Cont'd)

Average fiber diameter	4.2 $\mu$	3.7 $\mu$	3.5 $\mu$	3.3 $\mu$
Alkali resistance (weight loss)	2.0%	1.8%	1.0%	1.0%
Appearance of fibers after alkali resistance test	Discolored, brittle and disintegrated (see Fig. 1)	Discolored; disintegrated upon touch with hand	No change in both appearance and shape	No change in both appearance and shape (see Fig. 2)
Heat resistant temperature	700 - 720°C	700 - 720°C	840 - 860°C	840 - 860°C

## 1 Note:

- (1) All percentages are by weight.
- (2) The Comparative Example 1 indicates the customary rock fibers.
- 5 (3) The fibers of Comparative Example 2 are those of a composition not covered by the present invention.
- (4) The Comparative Example 3 correspond to the rock fibers disclosed in Japanese Patent
- 10 Application "Kokai" (Laid-open) No. 101,922/1979.
- (5) Testing method:
  - (a) Alkali resistance: 500 cc of 1 N NaOH and about 10 g (weighed precisely) of the sample are placed together in a tightly
  - 15 stoppered 1-liter polyethylene vessel and immersed in a hot water bath regulated at  $80 \pm 1^\circ\text{C}$ . After 24 hours, the sample is washed with clean water, dried, then measured the weight loss.
  - 20 (b) Heat-resistant temperature: A disc having a diameter of 500 mm, a thickness of 50-80 mm and a specific gravity of 0.5 is placed under a load of 10 g. The temperature of the disc is elevated at a rate of  $10^\circ\text{C}/$
  - 25 minute until  $500^\circ\text{C}$  and then at a rate of  $5^\circ\text{C}/\text{minute}$ . The temperature at which the sample has contracted in thickness by 10% is taken as the heat-resistant

1 temperature.

Fig. 1 is an electron scanning microscopic photograph (x 1,000) of the customary rock fibers after having been subjected to the alkali-resistance test described in the above procedure (a). The fibers were observed to be so deteriorated to show the roughness of the fiber surface and the occurrence of disintegrated fiber fragments.

Fig. 2 is an electron scanning microscopic photograph (x 1,000) of the inorganic fibers of this invention after having been subjected to the alkali resistance test described in the above procedure (a). It was observed that the fibers kept their original shape, neither rough surface nor fiber fragments being detectable, indicating that the alkali resistance has been improved to a great extent.

As is apparent from Table 2, the fibers of this invention are superior in alkali resistance to those of the Comparative Examples 1 and 2. The fibers of the Comparative Example 3 show that alkali resistance is nearly equal to those of this invention. However, the example of this invention shows the lower optimal fiberizing temperature, which indicates the possibility of a remarkable saving in the melting energy. The heat-resistant temperature of the fibers of this invention is higher than that of the customary rock fibers by nearly 140°C.

- 1       The inorganic fibers of this invention having  
the good alkali and heat resistances, as described  
above, can be manufactured at low cost on commercial  
scale and used chiefly as a replacement of asbestos  
5 in asbestos-cement boards.

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What is claimed is:

1. An alkali- and heat-resistant inorganic fiber comprising as major constituents

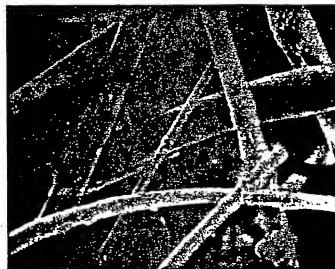
	% by weight
$\text{SiO}_2$	40 - 50
$\text{CaO}$	0 - 10
$\text{MgO}$	15 - 25
$\text{Fe}_2\text{O}_3 + \text{FeO}$	0 - 10
$\text{Al}_2\text{O}_3$	5 - 15
$\text{MnO}$	2 - 15

provided that the total amount of  $\text{CaO}$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{FeO}$  and  $\text{MnO}$  is limited within 20% by weight.

FIG. 1



FIG. 2







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# EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
D	<p>GB - A - 1 244 491 (CESKOSLOVENSKÁ AKADEMIE VED)</p> <p>* Page 2, lines 64-85 *</p> <p>--</p> <p>GB - A - 1 468 943 (NIPPON ASBESTOS)</p> <p>* Claims 1,5,6,10,12 *</p> <p>--</p> <p>GB - A - 2 011 379 (ROCKWOOL INTERNATIONAL)</p> <p>* Claim 1 *</p>	1	<p>C 03 C 13/00</p> <p>C 04 B 31/06</p>
	<p>&amp; JP - A - 54 101 922</p> <p>--</p> <p>CHEMICAL ABSTRACTS, vol. 92, no. 8, 25th February 1980, page 300, no. 63416k Columbus, Ohio, U.S.A.</p> <p>&amp; RO - A - 68 201 (INSTITUTUL DE CERCETARI SI PROIECTARI TEHNOLOGICE PENTRU STICLA SI CERAMICA FINA BUCURESTI) 30-06-1978</p> <p>* Abstract *</p> <p>--</p>	1	
	<p>CHEMICAL ABSTRACTS, vol. 90, no. 24, 11th June 1979, page 298, no. 191569h Columbus, Ohio, U.S.A.</p> <p>&amp; SU - A - 649 670 (ALL UNION) 28-02-1979</p> <p>* Abstract *</p> <p>--</p> <p>./.</p>	1	<p>CATEGORY OF CITED DOCUMENTS</p> <p>X: particularly relevant</p> <p>A: technological background</p> <p>O: non-written disclosure</p> <p>P: intermediate document</p> <p>T: theory or principle underlying the invention</p> <p>E: conflicting application</p> <p>D: document cited in the application</p> <p>L: citation for other reasons</p>
	<p>The present search report has been drawn up for all claims</p>		
Place of search The Hague		Date of completion of the search 24-04-1981	Examiner GAJ



## EUROPEAN SEARCH REPORT

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